

Claims:

1. A tubing expansion device comprising:
 - at least one expansion member adapted to expand a tubing by inducing a hoop stress in the tubing; and
 - at least one further expansion member adapted to expand the tubing by inducing a compressive yield of the tubing.
2. A tubing expansion device as claimed in claim 1, wherein the expansion device is adapted to be rotated and translated through tubing to be expanded.
3. A tubing expansion device as claimed in claim 1, wherein the expansion device is adapted to be advanced through tubing to be expanded without rotation.
4. A tubing expansion device as claimed in claim 1, wherein the device is arranged such that expansion of the tubing to a desired final diameter is carried out by the compressive yield inducing expansion member.
5. A tubing expansion device as claimed in claim 1, wherein the device is arranged such that expansion of the tubing to a desired final diameter is carried out using the hoop stress inducing expansion member.
6. A tubing expansion device as claimed in claim 1, wherein the hoop stress and compressive yield inducing expansion members are axially spaced.
7. A tubing expansion device as claimed in claim 1, wherein the hoop stress and compressive yield inducing expansion members are circumferentially spaced.
8. A tubing expansion device as claimed in claim 1, wherein the hoop stress and compressive yield inducing expansion members are arranged according to at least one parameter of a tubing to be expanded.

9. A tubing expansion device as claimed in claim 8, wherein the parameter is selected from the group comprising: a pre-expansion diameter of the tubing; a pre-expansion wall thickness of the tubing; a desired post expansion diameter of the tubing; a desired post expansion wall thickness of the tubing; a pre-expansion strength of the tubing; Young's Modulus of the tubing material; anticipated work hardening of the tubing during expansion; a desired post-expansion strength of the tubing; and an axial length of the tubing post-expansion.
10. A tubing expansion device as claimed in claim 1, wherein the expansion members are provided spaced alternately in an axial direction.
11. A tubing expansion device as claimed in claim 1, wherein the expansion members are provided spaced alternately in a circumferential direction.
12. A tubing expansion device as claimed in claim 1, wherein said hoop stress and compressive yield inducing expansion members are provided on respective separate portions coupled together to form the expansion device.
13. A tubing expansion device as claimed in claim 12, wherein the expansion device further comprises a hoop stress inducing expansion tool and a compressive yield inducing expansion tool, each carrying said respective hoop stress and compressive yield inducing expansion members.
14. A tubing expansion device as claimed in claim 12, wherein the portions are coupled together and restrained against relative rotation.
15. A tubing expansion device as claimed in claim 12, wherein at least one of said portions is rotatable relative to at least one other portion.

16. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member is adapted to contact the tubing over a majority of a circumference of the tubing.
17. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is adapted to contact the tubing over part of a circumference of the tubing.
18. A tubing expansion device as claimed in claim 17, wherein the compressive yield inducing expansion member is adapted to contact the tubing in a point contact.
19. A tubing expansion device as claimed in claim 17, wherein the compressive yield inducing expansion member is adapted to contact the tubing in a line contact.
20. A tubing expansion device as claimed in claim 1, comprising a plurality of hoop stress inducing expansion members.
21. A tubing expansion device as claimed in claim 20, wherein said hoop stress inducing expansion members describe progressively increasing expansion diameters in a direction along an axial length of the device.
22. A tubing expansion device as claimed in claim 1, comprising a plurality of compressive yield inducing expansion members.
23. A tubing expansion device as claimed in claim 22, wherein said compressive yield inducing expansion members are arranged to describe progressively increasing expansion diameters in a direction along an axial length of the device.
24. A tubing expansion device as claimed in claim 1, comprising a plurality of hoop stress inducing expansion portions each having at least one hoop stress inducing expansion member.

25. A tubing expansion device as claimed in claim 1, comprising a plurality of compressive yield inducing expansion portions each having at least one compressive yield inducing expansion member.
26. A tubing expansion device as claimed in claim 1, comprising a plurality of hoop stress inducing expansion portions each having at least one hoop stress inducing expansion member, and a plurality of compressive yield inducing expansion portions each having at least one compressive yield inducing expansion member, said hoop stress and compressive yield inducing expansion portions axially alternating along a length of the device.
27. A tubing expansion device as claimed in claim 1, comprising a plurality of hoop stress inducing expansion portions each having at least one hoop stress inducing expansion member, and a plurality of compressive yield inducing expansion portions each having at least one compressive yield inducing expansion member, wherein a plurality of said hoop stress inducing expansion portions are coupled together and joined to at least one compressive yield inducing expansion portion.
28. A tubing expansion device as claimed in claim 1, comprising a plurality of hoop stress inducing expansion portions each having at least one hoop stress inducing expansion member, and a plurality of compressive yield inducing expansion portions each having at least one compressive yield inducing expansion member, wherein a plurality of said compressive yield inducing expansion portions are coupled together and joined to at least one hoop stress inducing expansion portion.
29. A tubing expansion device as claimed in claim 1, comprising at least one hoop stress inducing expansion member and at least one compressive yield inducing expansion member provided on a single portion of the device.

30. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member comprises a fixed expansion member.
31. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member is fixed relative to a remainder of the device.
32. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member is formed integrally with a body of the expansion device.
33. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member is rotatable with respect to the tubing.
34. A tubing expansion device as claimed in claim 33, wherein the hoop stress inducing expansion member is rotatably mounted on a body of the device.
35. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member comprises a fixed diameter expansion member.
36. A tubing expansion device as claimed in claim 35, wherein the hoop stress inducing expansion member comprises an expansion cone.
37. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member comprises a compliant expansion member.
38. A tubing expansion device as claimed in claim 37, wherein the hoop stress inducing expansion member comprises a compliant cone.
39. A tubing expansion device as claimed in claim 1, comprising a hoop stress inducing expansion tool including a plurality of hoop stress inducing expansion

rollers mounted for rotation about an axis substantially perpendicular to an axis of the tool.

40. A tubing expansion device as claimed in claim 1, comprising a cone with a plurality of hoop stress inducing expansion rollers rotatably mounted on the cone.

41. A tubing expansion device as claimed in claim 1, wherein the hoop stress inducing expansion member takes the form of a collapsible expansion cone which is movable between a collapse position and an expansion position, in the expansion position, the cone adapted for expanding the tubing.

42. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member comprises a rotary expansion member, which is rotatable about an expansion member axis.

43. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is provided as part of a compressive yield inducing expansion member module releasably coupled to a body of the device as a unit.

44. A tubing expansion device as claimed in claim 43, wherein the compressive yield inducing expansion member is rotatably mounted on a spindle.

45. A tubing expansion device as claimed in claim 44, wherein the spindle is cantilevered and extends from a body of the device.

46. A tubing expansion device as claimed in claim 44, wherein the spindle is pivotally coupled to the body.

47. A tubing expansion device as claimed in claim 44, wherein an axis of the spindle is disposed at an angle with respect to a main axis of the device.

48. A tubing expansion device as claimed in claim 1, comprising a bearing between the compressive yield inducing expansion member and a body of the device, and a sealed lubrication system for containing lubricant to facilitate rotation of the compressive yield inducing expansion member relative to the body.
49. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is radially moveably mounted with respect to a body of the device, for movement towards an expansion configuration describing an expansion diameter for expanding tubing to a predetermined diameter.
50. A tubing expansion device as claimed in claim 49, wherein the compressive yield inducing expansion member is lockable in the extended configuration.
51. A tubing expansion device as claimed in claim 49, wherein the compressive yield inducing expansion member is biased radially inwardly.
52. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is moveable in response to applied fluid pressure.
53. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is moveable in response to an applied mechanical force.
54. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is radially moveable relative to a body of the device in response to both: a) an applied mechanical force; and b) an applied fluid pressure force.

55. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is pivotally mounted with respect to a body of the device for movement towards an extended configuration.
56. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is adapted to generate a drive force on the tubing for at least partly translating the device with respect to the tubing.
57. A tubing expansion device as claimed in claim 56, wherein the drive force is generated on rotation of the expansion device.
58. A tubing expansion device as claimed in claim 56, wherein the expansion device is adapted to be translated through the tubing by a combination of an external axial force and the generated drive force.
59. A tubing expansion device as claimed in claim 56, wherein the expansion device is adapted to be translated through the tubing without an externally applied axial force.
60. A tubing expansion device as claimed in claim 56, wherein an axis of the compressive yield expansion member is skewed with respect to a body of the device.
61. A tubing expansion device as claimed in claim 56, wherein the device comprises a plurality of compressive yield inducing expansion members, and wherein the members are circumferentially spaced and helically oriented with respect to a body of the device.
62. A tubing expansion device as claimed in claim 56, wherein the compressive yield inducing expansion member includes a gripping surface for gripping the tubing to impart a drive force on the tubing.

63. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is adapted to expand the tubing by less than 50% of the total expansion of the tubing.
64. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is adapted to expand the tubing by less than 25% of the total expansion of the tubing.
65. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member is adapted to expand the tubing by less than 10% of the total expansion of the tubing.
66. A tubing expansion device as claimed in claim 1, wherein at least one of the hoop stress inducing and compressive yield inducing expansion members has an expansion member axis, and wherein said axis is non-parallel with respect to a main axis of the device.
67. A tubing expansion device as claimed in claim 1, wherein the compressive yield inducing expansion member comprises a rotary expansion member, which is rotatable about an expansion member axis, and wherein said axis is non-parallel with respect to a main axis of the device.
68. A tubing expansion device as claimed in claim 67, wherein said expansion member axis converges with the tool main axis towards a leading end of the device.
69. A tubing expansion device as claimed in claim 67, wherein the compressive yield inducing expansion member is rotatably mounted on a spindle, and wherein the spindle is disposed non-parallel with respect to the device main axis.

70. A tubing expansion device as claimed in claim 67, wherein the compressive yield inducing expansion member includes a spindle which is rotatable relative to a body of the device, and wherein the spindle is disposed non-parallel with respect to the device main axis.

71. A method of expanding tubing, the method comprising the steps of:
expanding the tubing at least in part by inducing a hoop stress in the tubing;
and
expanding the tubing at least in part by inducing a compressive yield of the tubing.

72. A method as claimed in claim 71, comprising providing an expansion device having at least one hoop stress inducing expansion member and at least one compressive yield inducing expansion member.

73. A method as claimed in claim 71, comprising expanding the tubing to a first diameter by inducing one of a hoop stress in the tubing and a compressive yield of the tubing, and subsequently expanding the tubing to a second, greater diameter by the other one of inducing a hoop stress in the tubing and a compressive yield of the tubing.

74. A method as claimed in claim 73, comprising providing an expansion device having at least one hoop stress inducing expansion member and at least one compressive yield inducing expansion member, and arranging said hoop stress and compressive yield inducing expansion members such that on translation of the tool through the tubing, expansion of the tubing to a first diameter is carried out using the hoop stress inducing expansion member, and expansion to a second, greater diameter is carried out using the compressive yield inducing expansion member.

75. A method as claimed in claim 73, comprising providing an expansion device having at least one hoop stress inducing expansion member and at least one

compressive yield inducing expansion member, and arranging said hoop stress and compressive yield inducing expansion members such that on translation of the tool through the tubing, expansion of the tubing to a first diameter is carried out using the compressive yield inducing expansion member, and expansion to a second, greater diameter is carried out using the hoop stress inducing expansion member.

76. A method as claimed in claim 74, comprising arranging the hoop stress inducing expansion member and the compressive yield inducing expansion member relative to each other according to at least one parameter of tubing to be expanded.

77. A method as claimed in claim 76 comprising selecting the parameter from the group comprising: a pre-expansion diameter of the tubing; a pre-expansion wall thickness of the tubing; a desired post-expansion diameter of the tubing; a desired post-expansion wall thickness of the tubing; a pre-expansion yield strength of the tubing; the Young's Modulus of the tubing material; anticipated work hardening of the tubing during expansion; a desired post-expansion strength of the tubing; and an axial length of the tubing post-expansion.

78. A method as claimed in claim 71, comprising expanding the tubing without any change in axial length thereof.

79. A method as claimed in claim 71, comprising expanding the tubing by progressively increasing amounts to a desired final diameter.

80. A method as claimed in claim 71, comprising providing a plurality of expansion tool portions, at least one expansion tool portion carrying at least one hoop stress inducing expansion member and at least one other expansion tool portion carrying at least one compressive yield inducing expansion member.

81. A method as claimed in claim 80, comprising providing at least one of the expansion portions with a combination of hoop stress inducing and compressive yield inducing expansion members.
82. A method as claimed in claim 80, comprising determining at least one parameter of the tubing; and coupling the portions together in a desired axial arrangement selected according to the determined parameter.
83. A method as claimed in claim 82, comprising selecting the parameter from the group comprising: a pre-expansion diameter of the tubing; a pre-expansion wall thickness of the tubing; a desired post-expansion diameter of the tubing; a desired post-expansion wall thickness of the tubing; a pre-expansion yield strength of the tubing; the Young's Modulus of the tubing material; anticipated work hardening of the tubing during expansion; a desired post-expansion strength of the tubing; and an axial length of the tubing post expansion.
84. A method as claimed in claim 71, comprising inducing a hoop stress in the tubing by bringing an expansion member into contact with a majority of a circumference of the tubing.
85. A method as claimed in claim 71, comprising inducing a compressive yield by bringing an expansion member into a point contact with the tubing, and rotating said expansion member around a circumference of the tubing.
86. A method as claimed in claim 71, comprising inducing a compressive yield by bringing an expansion member into a line contact with the tubing, and rotating said expansion member around a circumference of the tubing.
87. A method as claimed in claim 71, comprising rotating the expansion device to generate an axial drive force for at least partly translating the device through the tubing.

88. A method as claimed in claim 87, comprising providing at least one compressive yield inducing expansion member with an axis of said expansion member disposed non-parallel with respect to a main axis of the device.

89. A method as claimed in claim 87, comprising coupling a hoop stress inducing expansion cone to an expansion portion carrying said compressive yield inducing expansion member, and driving the cone through the tubing at least in part by said generated drive force.

90. A method of expanding tubing, the method comprising the steps of:
determining at least one parameter of a tubing;
providing a tubing expansion device having at least one hoop stress inducing expansion member and at least one compressive yield inducing expansion member;
arranging the at least one hoop stress inducing expansion member and the at least one compressive yield inducing expansion member relative to each other according to the at least one parameter; and
translating the tubing expansion device through the tubing.

91. A method as claimed in claim 90, wherein the step of providing said expansion device comprises selecting the tubing expansion device from a group comprising a plurality of expansion devices each having a different arrangement of hoop stress and compressive yield inducing expansion members.

92. A method as claimed in claim 90, comprising selecting the parameter from the group comprising: a pre-expansion diameter of the tubing; a pre-expansion wall thickness of the tubing; a desired post-expansion diameter of the tubing; a desired post-expansion wall thickness of the tubing; a pre-expansion yield strength of the tubing; the Young's Modulus of the tubing material; anticipated work hardening of the tubing during expansion; a desired post-expansion strength of the tubing; and an axial length of the tubing post-expansion.

93. A tubing expansion device comprising at least one fixed expansion member; and

at least one rotary expansion member mounted for rotation with respect to a body of the tool.

94. A method of expanding tubing, the method comprising the steps of:

providing a tubing expansion device having at least one fixed expansion member and at least one rotary expansion member mounted for rotation with respect to a body of the tool; and

translating the tool through tubing to be expanded to expand the tubing in part by the fixed expansion member and in part by the rotary expansion member.